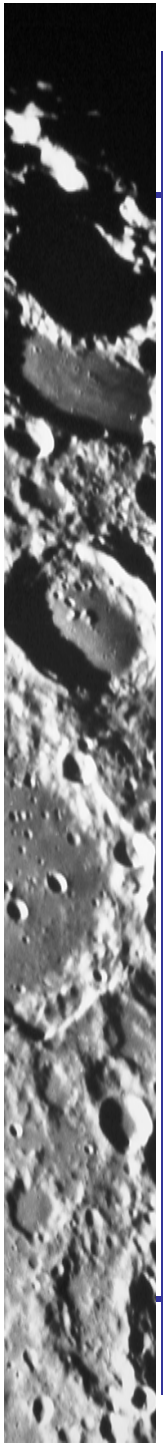
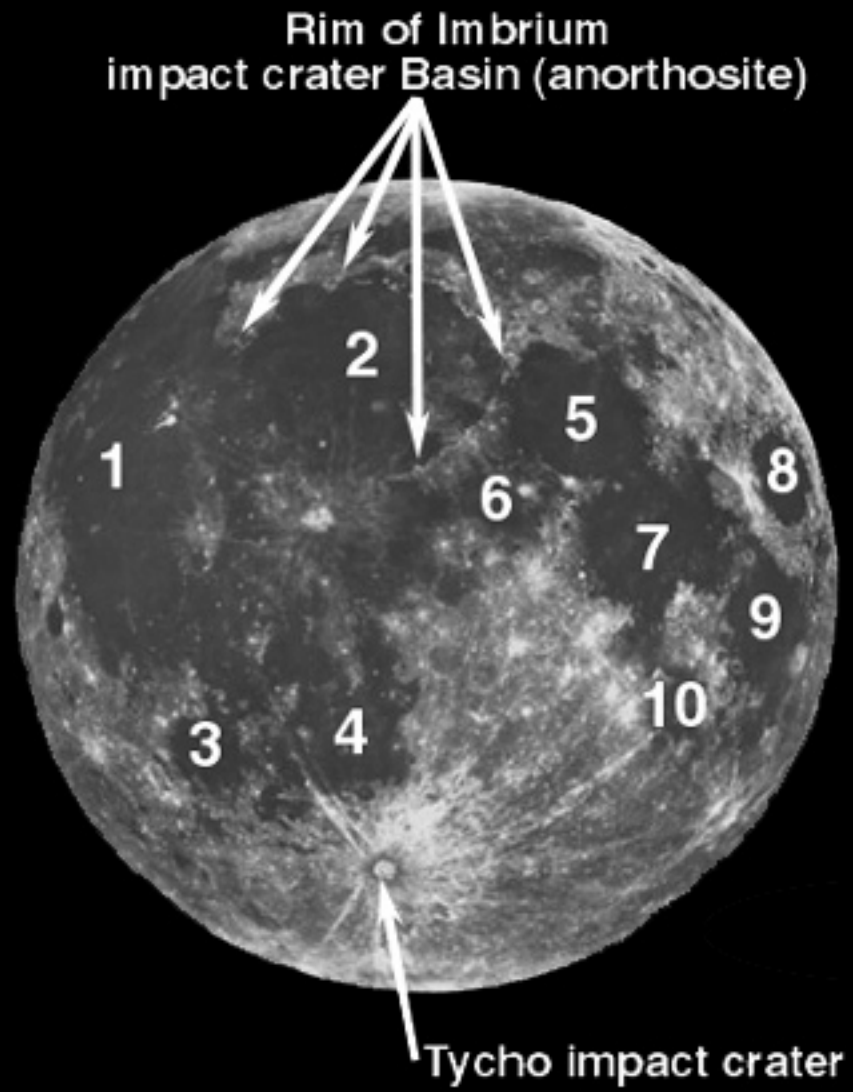


Lunar Exploration Initiative

Briefing Topic:

Apollo Traverses and Summary of Science Discoveries

David A. Kring



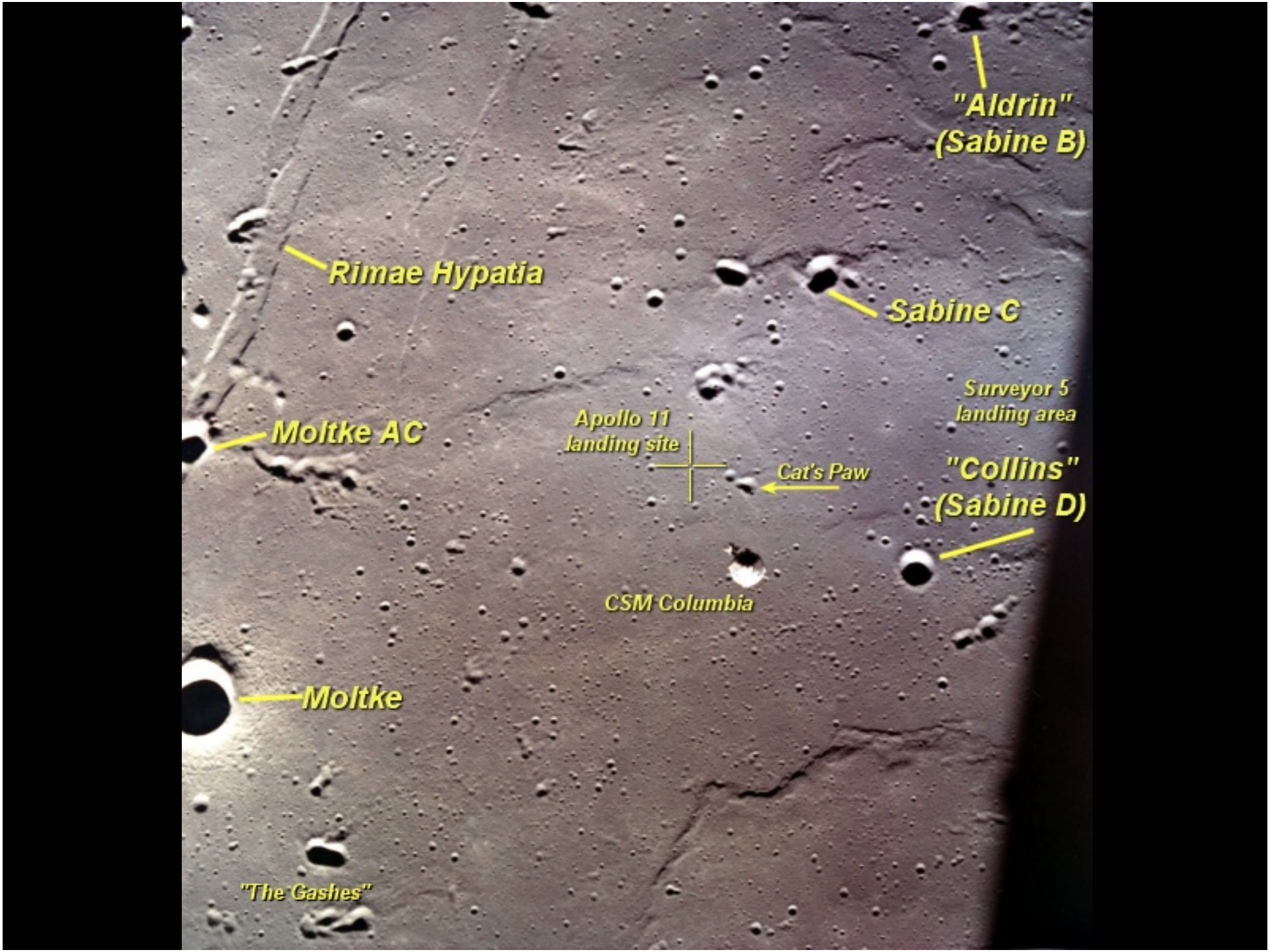
Maria of the Nearside of the Moon

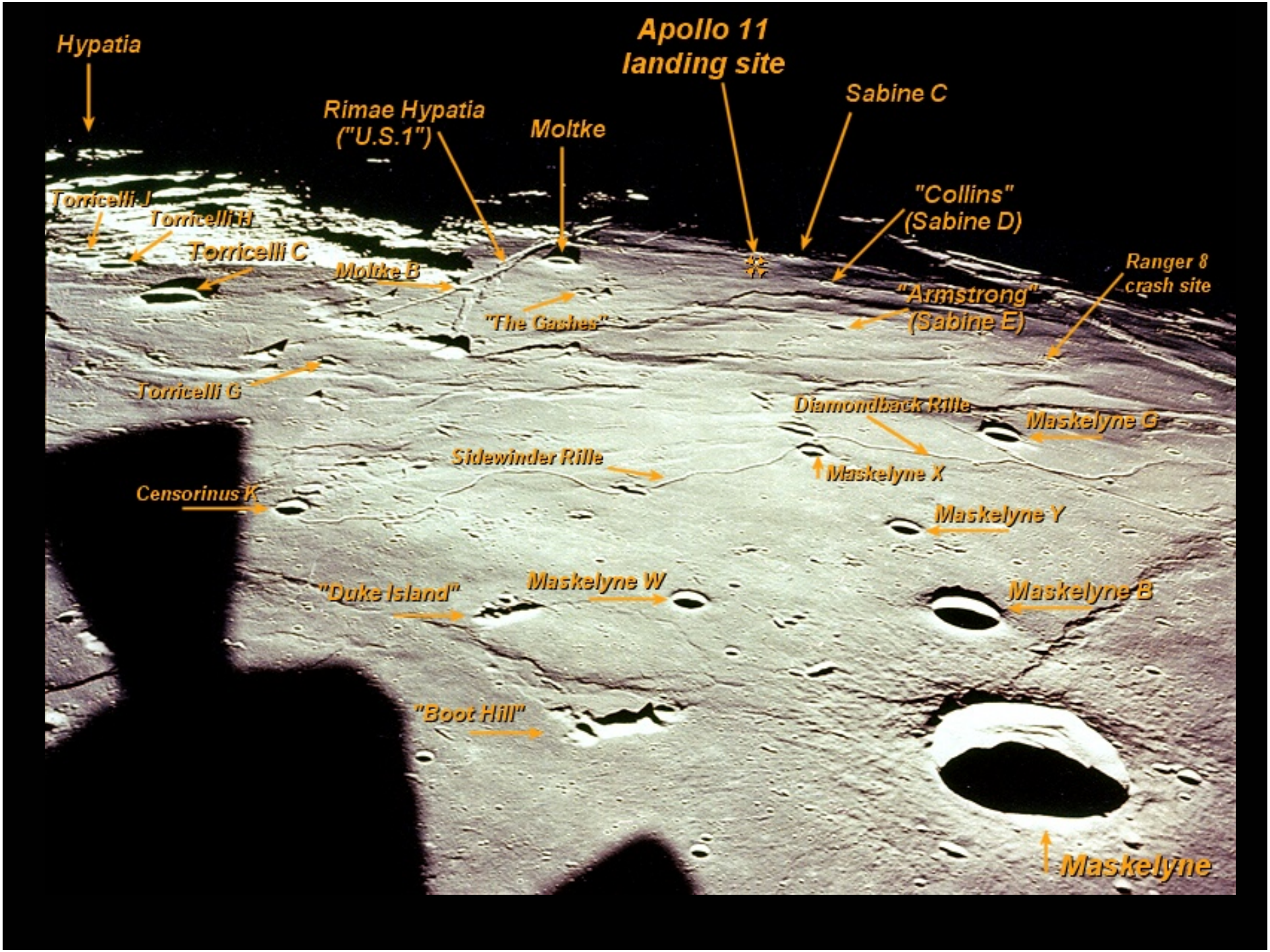
1. Oceanus Procellarum (Ocean of Storms)
2. Mare Imbrium (Ocean of Rains)
3. Mare Humorum (Sea of Moisture)
4. Mare Nubium (Sea of Clouds)
5. Mare Serenitatis (Sea of Serenity)
6. Mare Vaporum (Sea of Vapor)
7. Mare Tranquillitatis (Sea of Tranquility)
8. Mare Crisium (Sea of Crises)
9. Mare Fecunditatis (Sea of Fertility)
10. Mare Nectaris (Sea of Nectar)

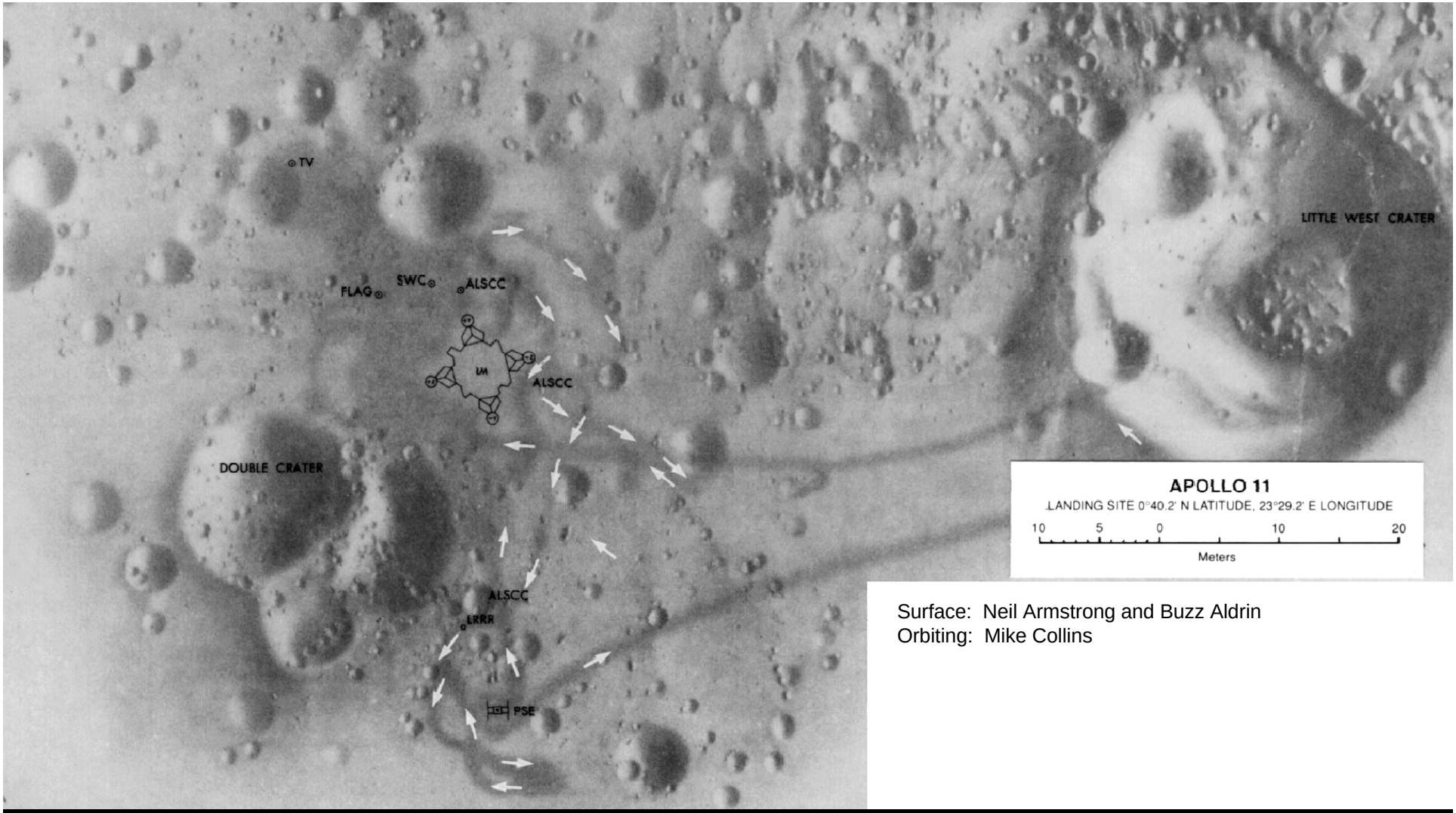

Apollo 15
Apollo 17
Luna 24
Luna 20
Apollo 11
Apollo 12
Apollo 14
Luna 16
Apollo 16

Apollo 11 Mare Tranquillitatis

Objectives:	Sample relatively old mare surface
Results:	Basalts high in Fe and Ti Basalts are 3.57 to 3.88 Ga Feldspathic lithic fragments found (a few percent of samples)
Conclusions:	Water not important Maria are very old Maria are volcanic At least two chemically distinct basalts of different ages suggest at least 2 lava flows occur at landing site Feldspathic material is ejecta from highlands Moon formed as a magma ocean and the highlands represent the initial anorthositic crust that floated on magma ocean Most craters have an impact origin and are not volcanic
Other notes:	Prime mission was not a science mission; rather, it was to land safely on the Moon and return to Earth


"Aldrin"
(Sabine B)
Rimae Hypatia
Sabine C
Surveyor 5
landing area
Apollo 11
landing site
Moltke AC
Cat's Paw
"Collins"
(Sabine D)
CSM Columbia
Moltke
"The Gashes"


Hypatia
Apollo 11
landing site
Sabine C
Rimae Hypatia
("U.S.1")
Moltke
Torricelli J
Torricelli H
Torricelli C
"Collins"
(Sabine D)
Moltke B
Ranger 8
crash site
"The Gashes"
"Armstrong"
(Sabine E)
Torricelli G
Diamondback Rille
Maskelyne G
Sidewinder Rille
Maskelyne X
Censorinus K
Maskelyne Y
"Duke Island"
Maskelyne W
Maskelyne B
"Boot Hill"
Maskelyne



Surface: Neil Armstrong and Buzz Aldrin
Orbiting: Mike Collins

Apollo 11 Mare Tranquillitatis

Objectives:	Sample relatively old mare surface
Results:	Basalts high in Fe and Ti Basalts are 3.57 to 3.88 Ga Feldspathic lithic fragments found (a few percent of samples)
Conclusions:	Water not important Maria are very old Maria are volcanic At least two chemically distinct basalts of different ages suggest at least 2 lava flows occur at landing site Feldspathic material is ejecta from highlands Moon formed as a magma ocean and the highlands represent the initial anorthositic crust that floated on magma ocean Most craters have an impact origin and are not volcanic
Other notes:	Prime mission was not a science mission; rather, it was to land safely on the Moon and return to Earth

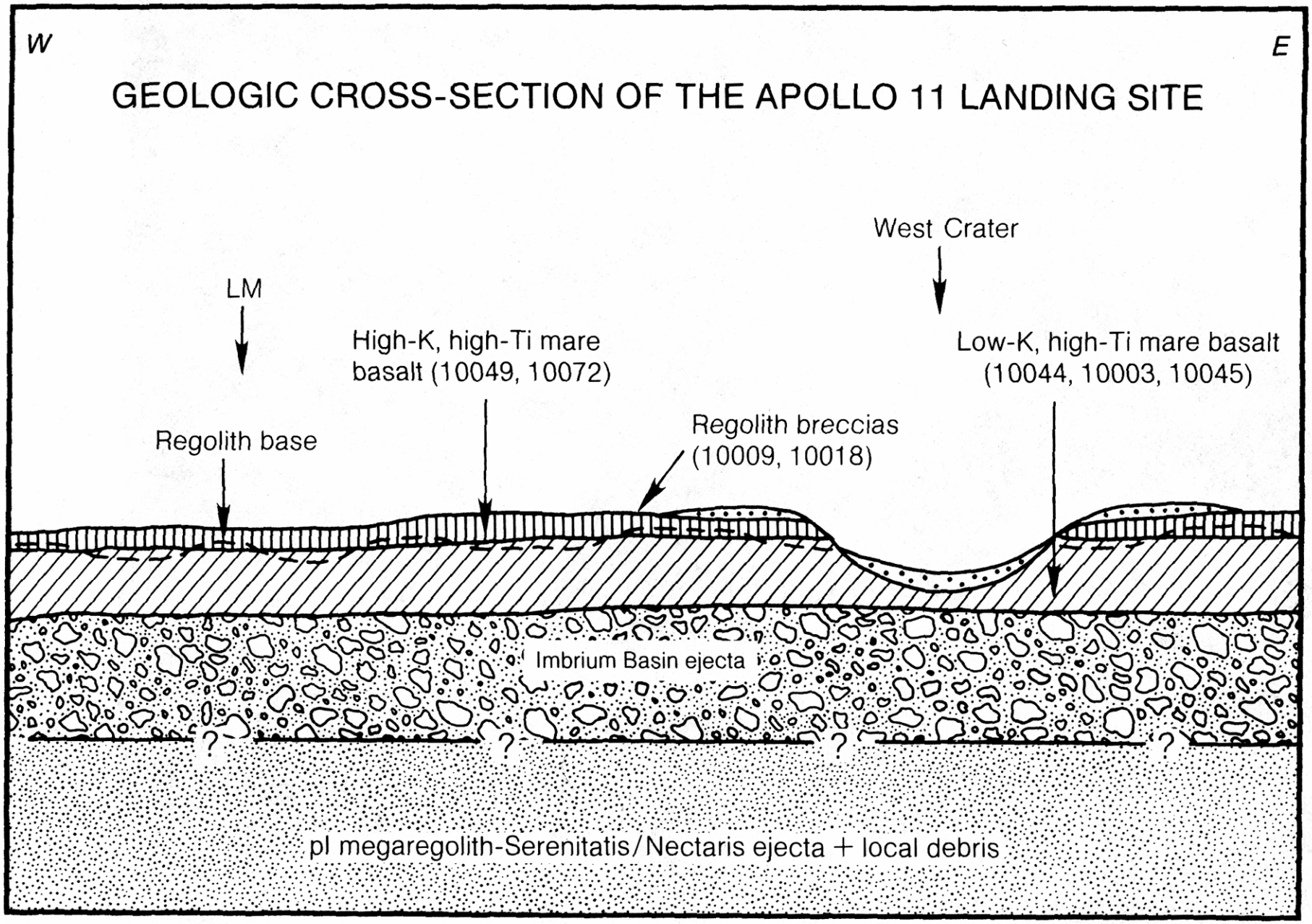
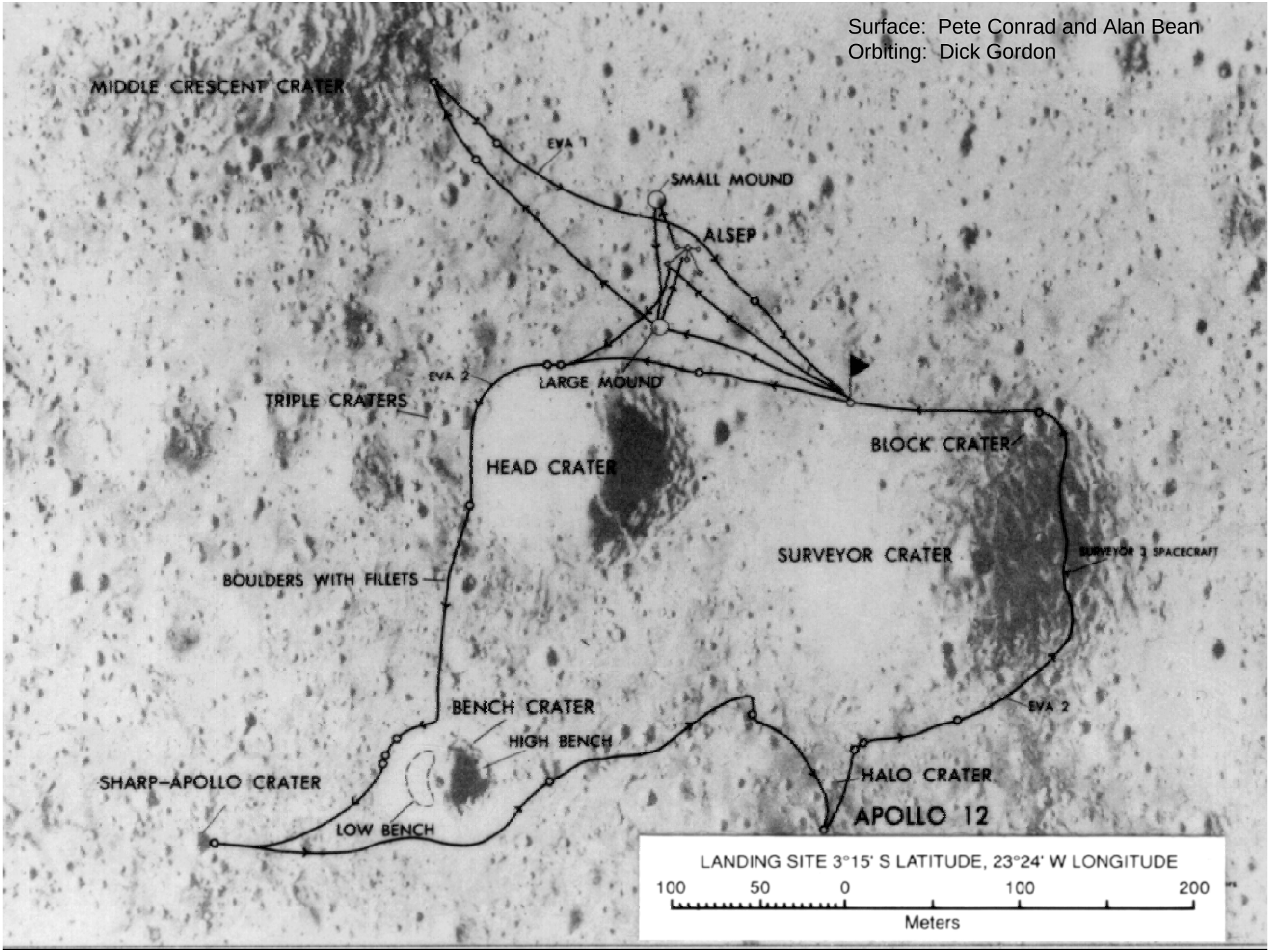


Figure credit: Lunar Sourcebook

Apollo 12 Oceanus Procellarum

Objectives:	Sample relatively young mare (less cratered surfaces than at Apollo 11 site) Sample possible ray from Copernicus impact crater (400 km north of landing site)
Results:	Basalts are approximately 3.29 to 3.08 Ga, representing three chemically distinct groups KREEP component detected in agglutinate glasses and polymict breccias
Conclusions:	“Young” mare are actually old Copernicus may have formed ~0.9 Ga, although it is not clear if the samples collected really are from the crater “Granite” exists on the Moon
Other notes:	Another objective was to land near Surveyor 3; crew successfully landed within 200 m of Surveyor 3


Surface: Pete Conrad and Alan Bean
Orbiting: Dick Gordon
MIDDLE CRESCENT CRATER
EVA 1
SMALL MOUND
ALSEP
EVA 2
LARGE MOUND
TRIPLE CRATERS
HEAD CRATER
BLOCK CRATER
SURVEYOR CRATER
SURVEYOR 3 SPACECRAFT
BOULDERS WITH FILLETS
BENCH CRATER
HIGH BENCH
EVA 2
SHARP-APOLLO CRATER
HALO CRATER
LOW BENCH
APOLLO 12
LANDING SITE 3°15' S LATITUDE, 23°24' W LONGITUDE
100 50 0 100 200
Meters

Apollo 12 Oceanus Procellarum

Objectives:	Sample relatively young mare (less cratered surfaces than at Apollo 11 site) Sample possible ray from Copernicus impact crater (400 km north of landing site)
Results:	Basalts are approximately 3.29 to 3.08 Ga, representing three chemically distinct groups KREEP component detected in agglutinate glasses and polymict breccias
Conclusions:	“Young” mare are actually old Copernicus may have formed ~0.9 Ga, although it is not clear if the samples collected really are from the crater “Granite” exists on the Moon
Other notes:	Another objective was to land near Surveyor 3; crew successfully landed within 200 m of Surveyor 3

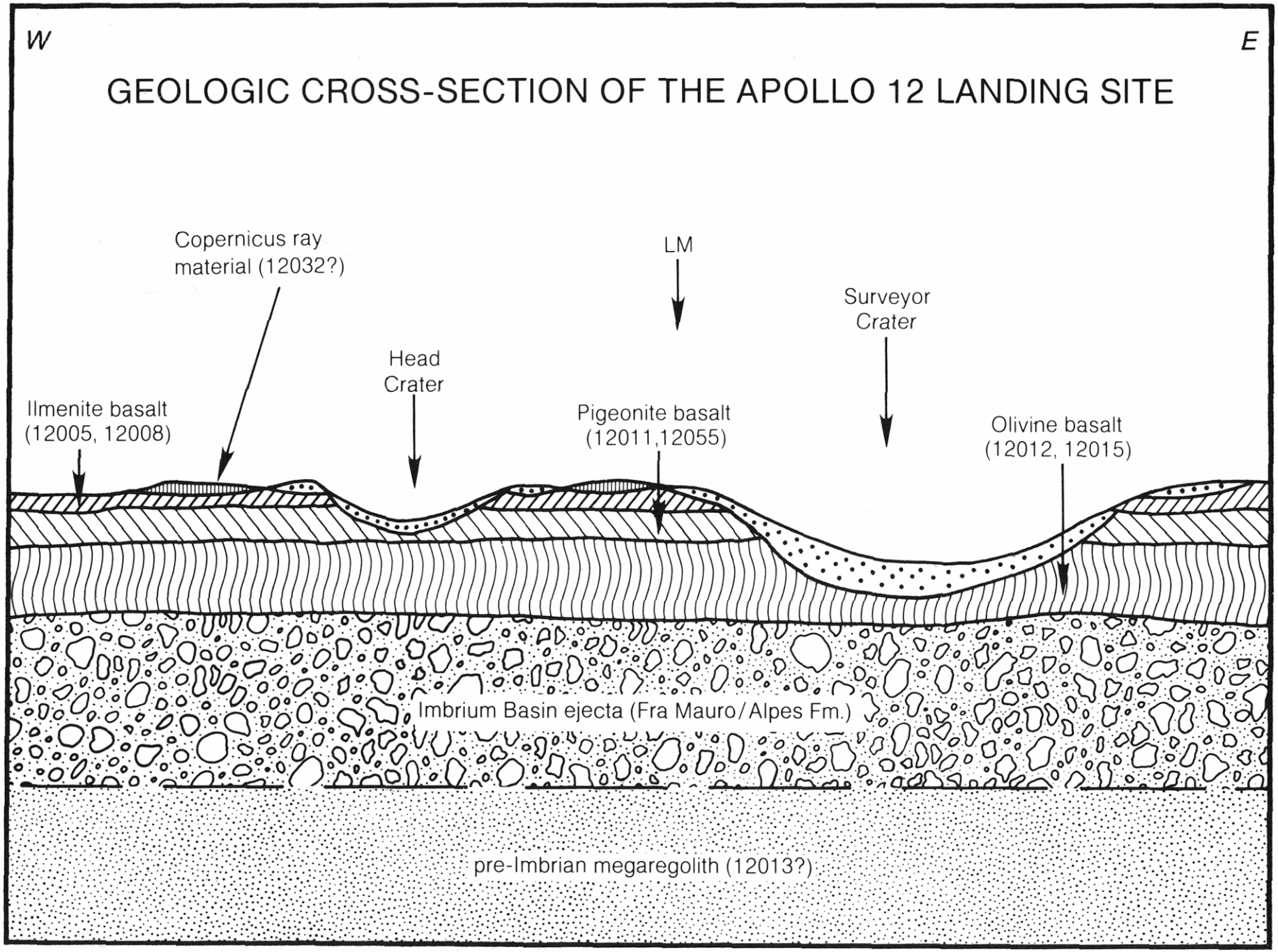
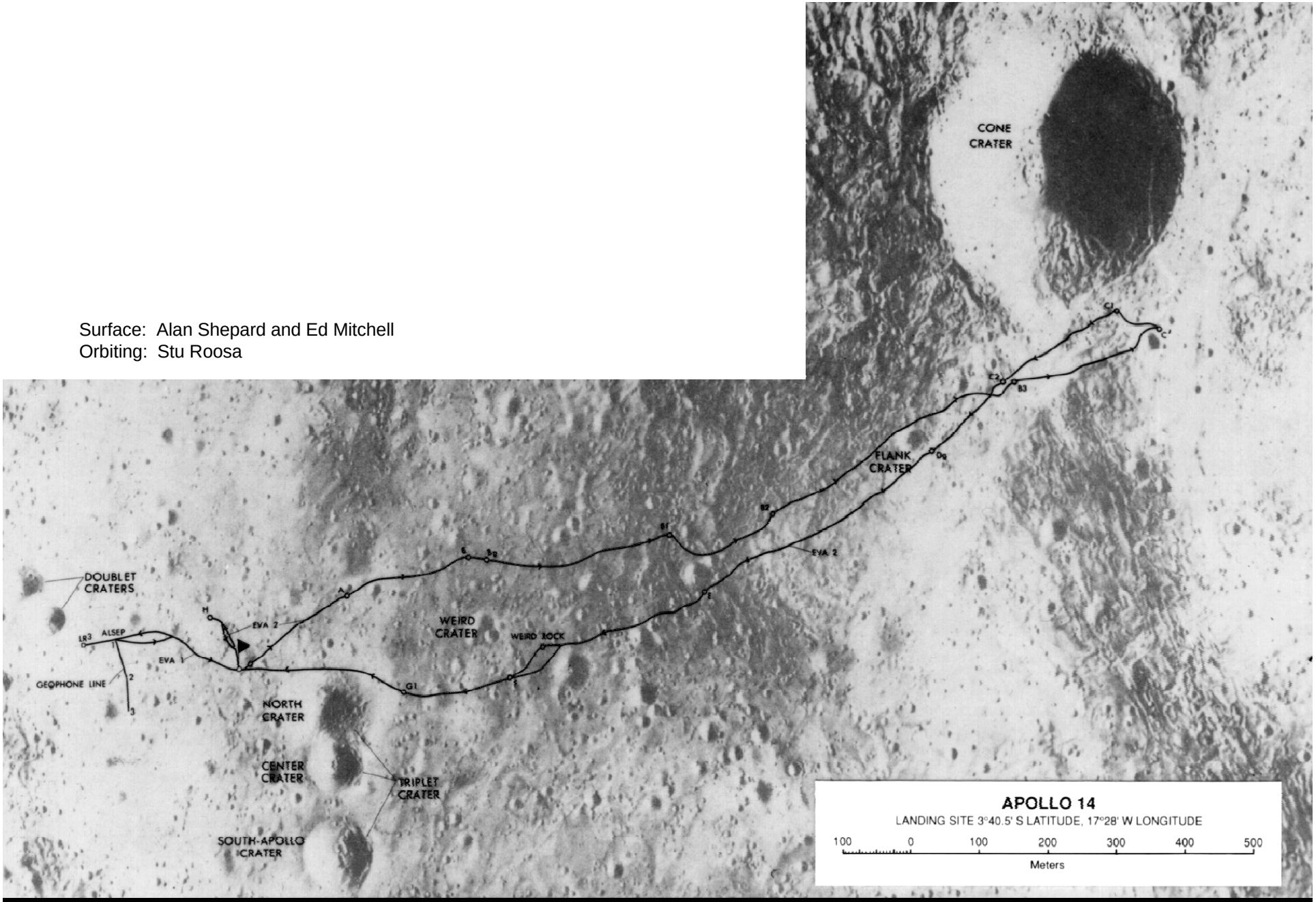


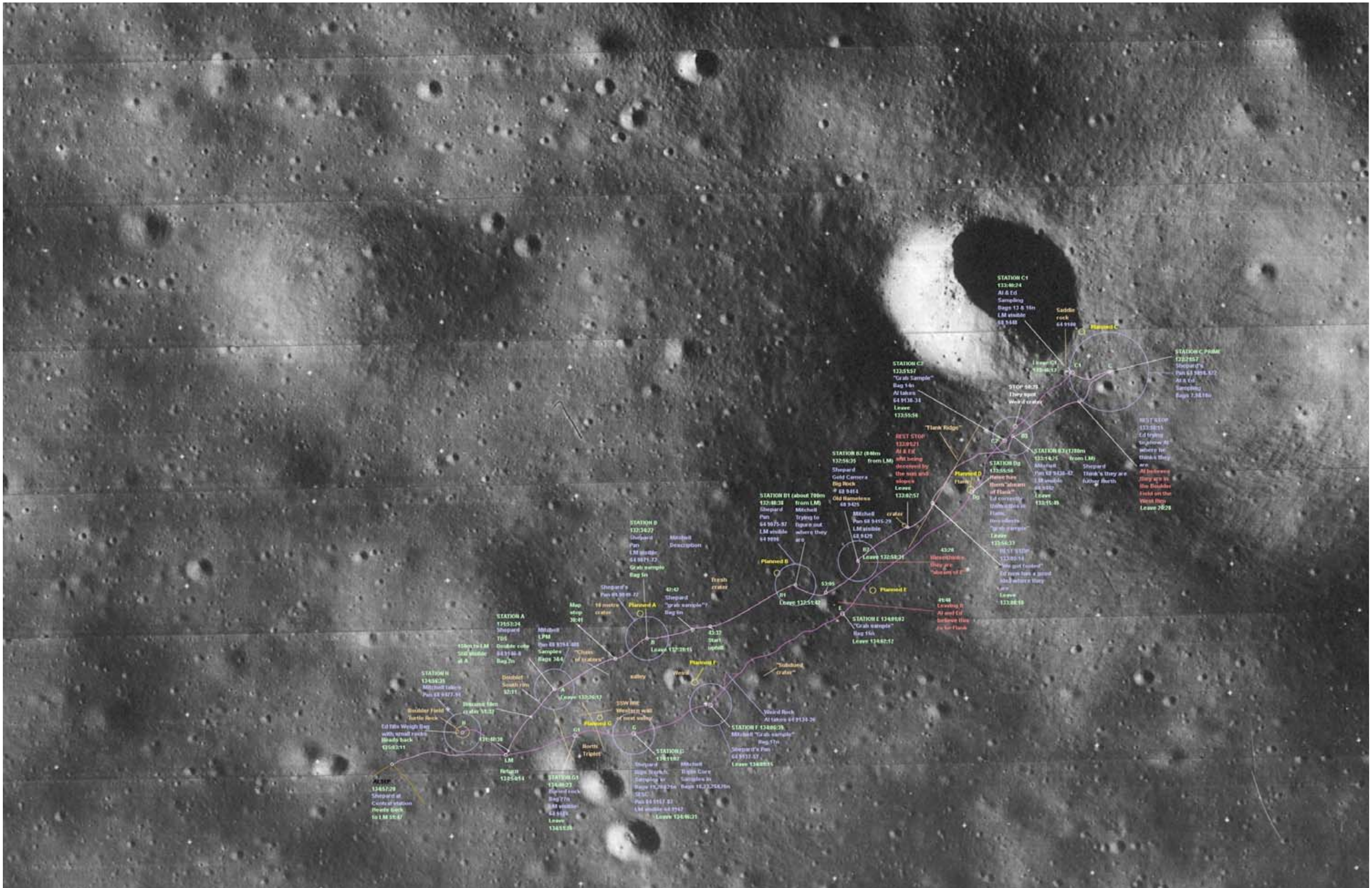
Figure credit: Lunar Sourcebook

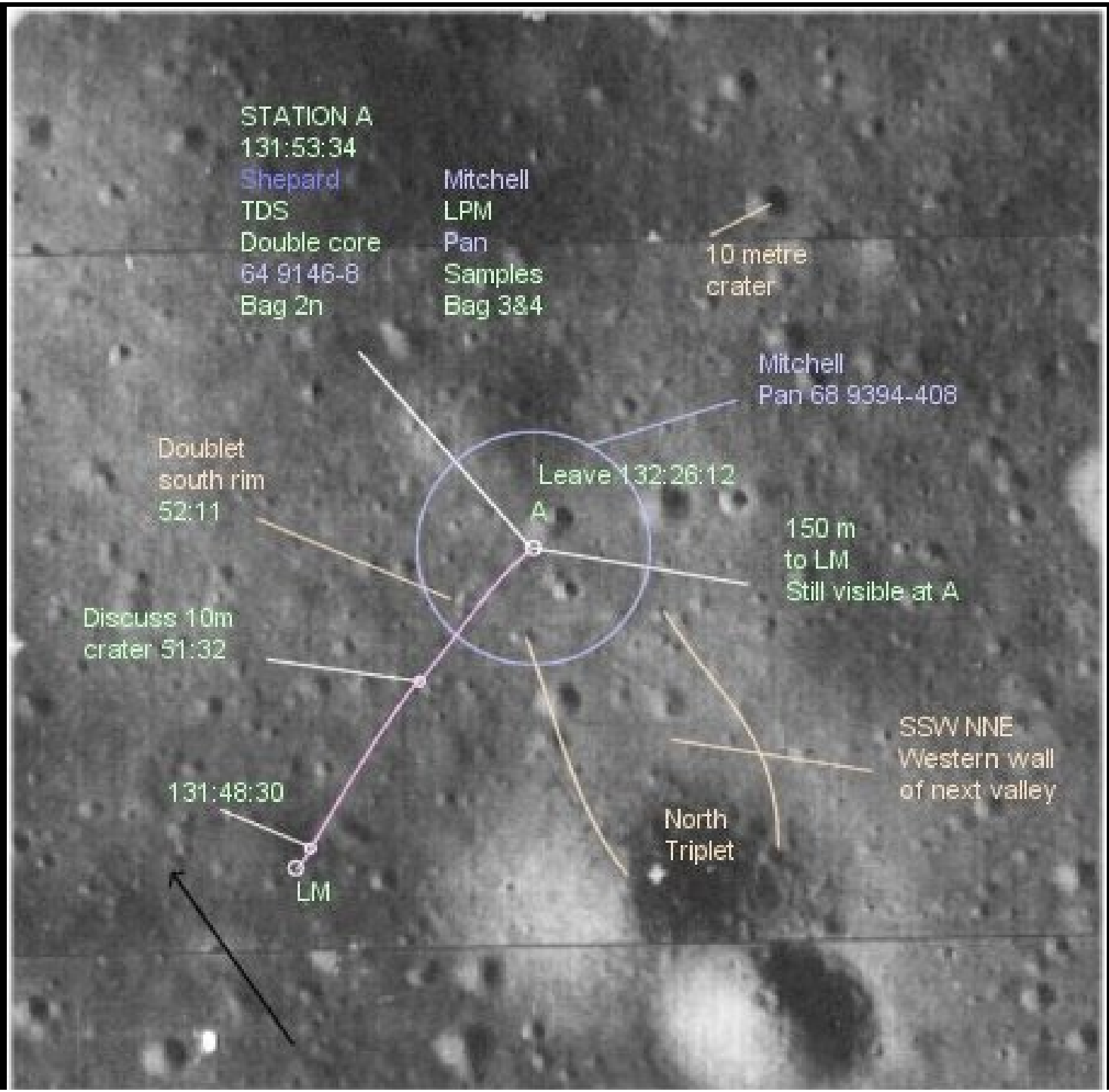
Apollo 14 Fra Mauro

Objectives:	Sample highland material Sample impact ejecta from the Imbrium basin, to help calibrate lunar stratigraphic record and to potentially sample material excavated from deep within highland crust
Results:	Complex fragmental breccias, impact melt breccias, and clast-poor impact melts discovered, generally with basaltic and KREEP-rich compositions (Low-K and High-K Fra Mauro “basalts”) Breccias dominantly 3.9 to 4.0 Ga
Conclusions:	Region is an ejecta blanket of Imbrium basin Imbrium basin formed ~3.9-4.0 Ga Trace-element-rich rocks are very abundant

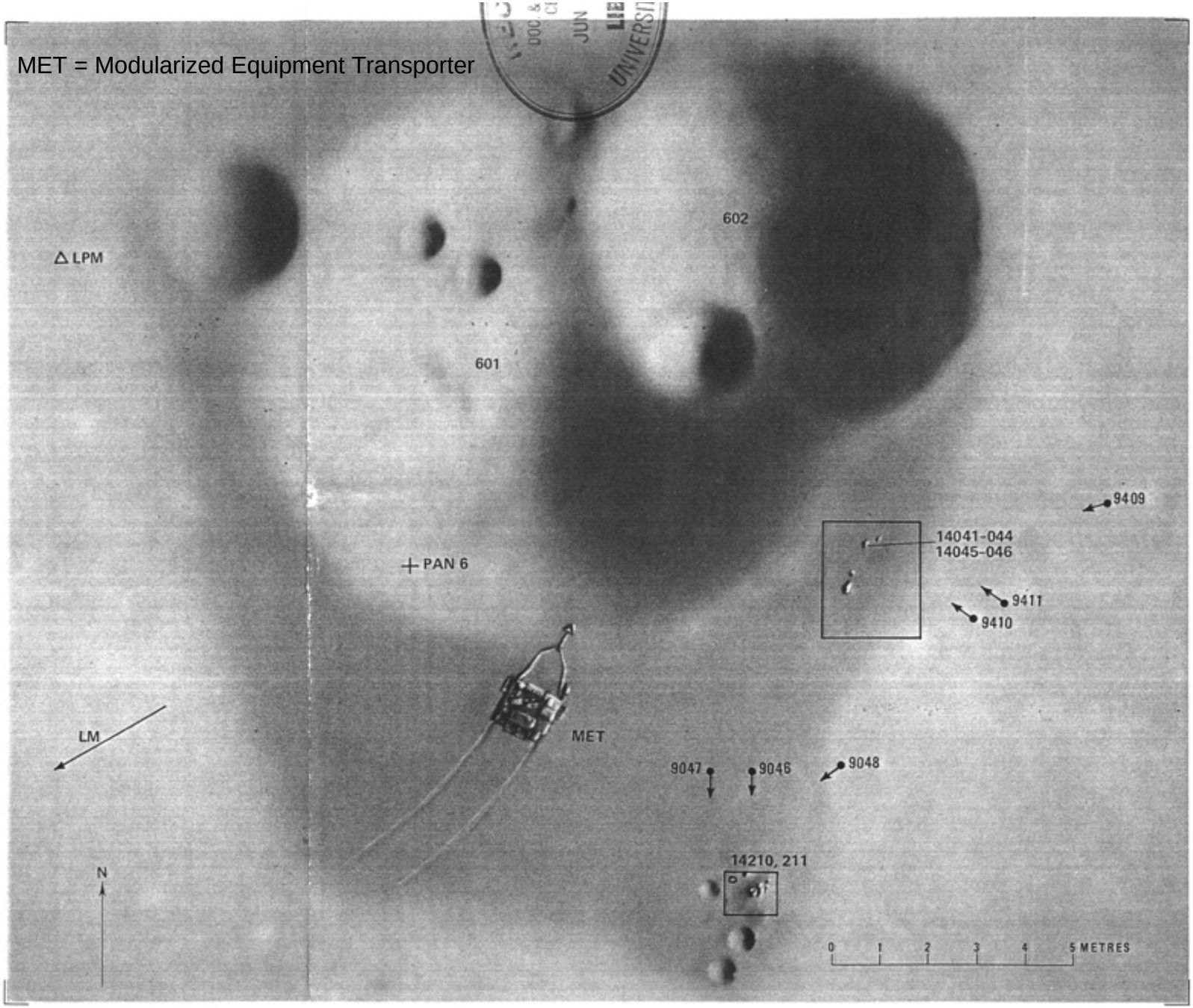
Surface: Alan Shepard and Ed Mitchell
Orbiting: Stu Roosa




STATION C1
133:40:24
Al & Ed
Sampling
Saddle
rock
Planned C
STATION C PRIME
Shepard's
Al & Ed
Sampling
STATION C'
133:51:57
"Grab Sample"
Bag 14n
Al takes
64 9138-34
Leave
133:55:56
STOP 58:29
They spot
Weird crater
"Flank Ridge"
REST STOP
Al & Ed
still being
deceived by
the sun and
slopes
Leave
133:02:57
STATION B3 (1200m
from LM)
Mitchell
LM visible
Leave
Shepard
Think's they are
futher North
STATION Dg
Leave
REST STOP
Ed trying
to show Al
where he
thinks they
are
Al believe
they are in
the Boulder
Field on the
West Rim
Planned D
Flank
STATION B2 (840m
132:56:35
from LM)
Shepard
Gold Camera
Big Rock
68 9414
Old Nameless
68 9425
Mitchell
Pan 68 9415-29
LM visible
68 9429
crater
Leave 132:58:31
43:29
"We got fooled"
STATION B1 (about 700m
132:48:38
from LM)
Shepard
Pan
64 9875-97
LM visible
64 9896
Mitchell
Trying to
figure out
where they
are
Planned B
53:05
Planned E
Leaving E
Al and Ed
believe this
is for Flank
STATION E
"Grab sample"
Bag 15n
Leave
STATION B
132:34:22
Shepard
Pan
LM visible
Grab sample
Bag 5n
Mitchell
Description
Fresh
crater
Shepard's
Planned A
10 metre
crater
Map
stop
30:41
43:42
Shepard
"grab sample"?
Bag 6n
43:32
Start
uphill
B
Leave 132:39:15
STATION A
131:53:34
Shepard
TDS
Double core
Bag 2n
Mitchell
LPM
Samples
Bags 3&4
"Chain
of craters"
valley
Weird
Planned F
"Subdued
crater"
Still visible
at A
STATION H
134:56:35
Mitchell takes
Doublet
South rim
A
Boulder Field
Turtle Rock
Planned G
G1
G
Weird Rock
STATION F
Mitchell "Grab sample"
Shepard's Pan
LM
North
Triplet
STATION G
Shepard
Mitchell
Triple Core
Samples in
SESC
Leave 134:46:21
ALSEP
134:57:29
Shepard at
Central station
Heads back
to LM 59:47
STATION G1
Leave


STATION A
131:53:34
Shepard
TDS
Double core
64 9146-8
Bag 2n
Mitchell
LPM
Pan
Samples
Bag 3&4
10 metre
crater
Mitchell
Pan 68 9394-408
Doublet
south rim
52:11
Leave 132:26:12
A
150 m
to LM
Still visible at A
Discuss 10m
crater 51:32
SSW NNE
Western wall
of next valley
131:48:30
North
Triplet
LM

MET = Modularized Equipment Transporter



Shaded relief by Patricia M. Bridges

SHADED RELIEF MAP OF STATION A

Apollo 14 Fra Mauro

Objectives: Sample highland material
Sample impact ejecta from the Imbrium basin,
to help calibrate lunar stratigraphic record and
to potentially sample material excavated from deep within highland crust

Results: Complex fragmental breccias, impact melt breccias,
and clast-poor impact melts discovered,
generally with basaltic and KREEP-rich compositions
(Low-K and High-K Fra Mauro “basalts”)
Breccias dominantly 3.9 to 4.0 Ga

Conclusions: Region is an ejecta blanket of Imbrium basin
Imbrium basin formed ~3.9-4.0 Ga
Trace-element-rich rocks are very abundant

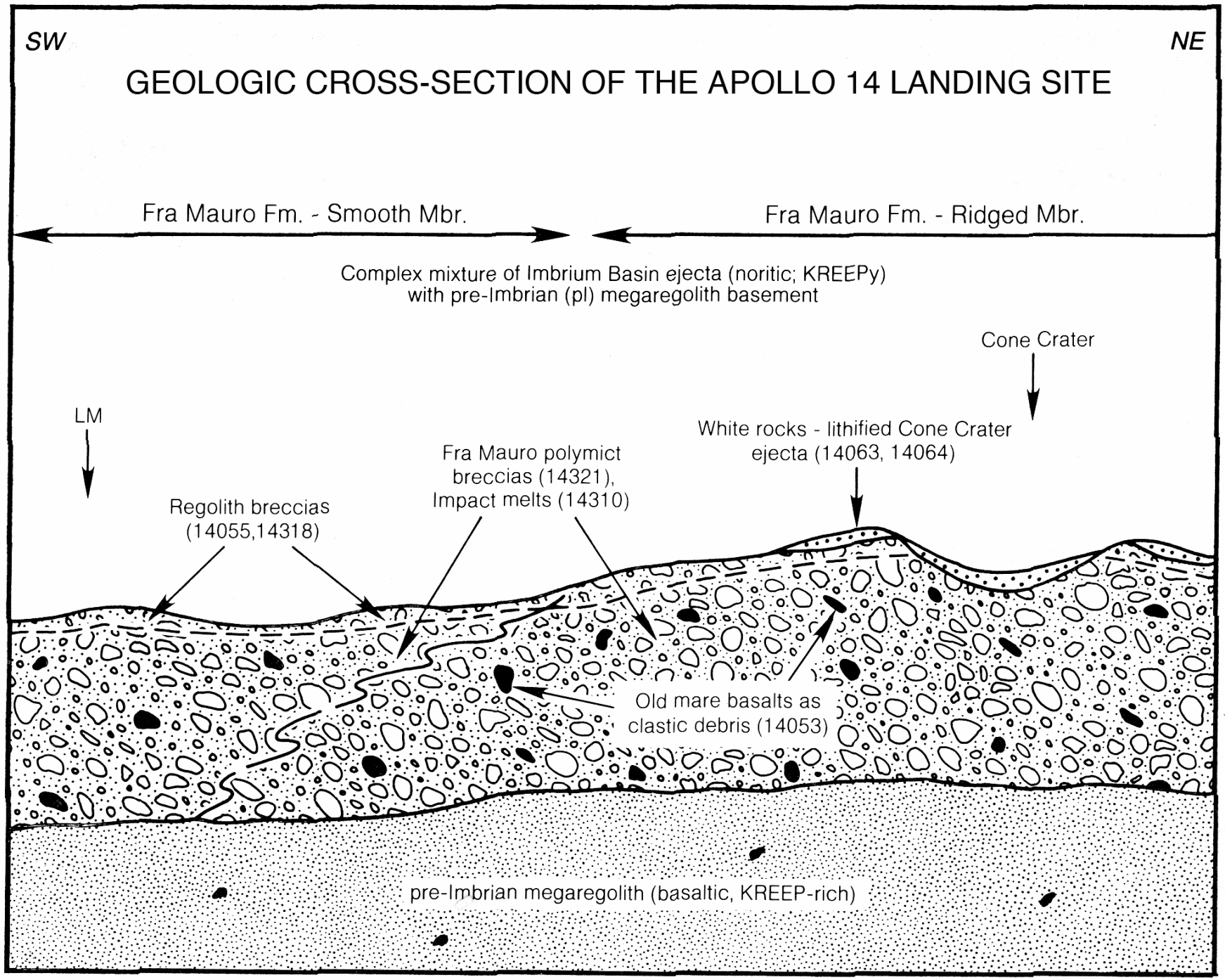
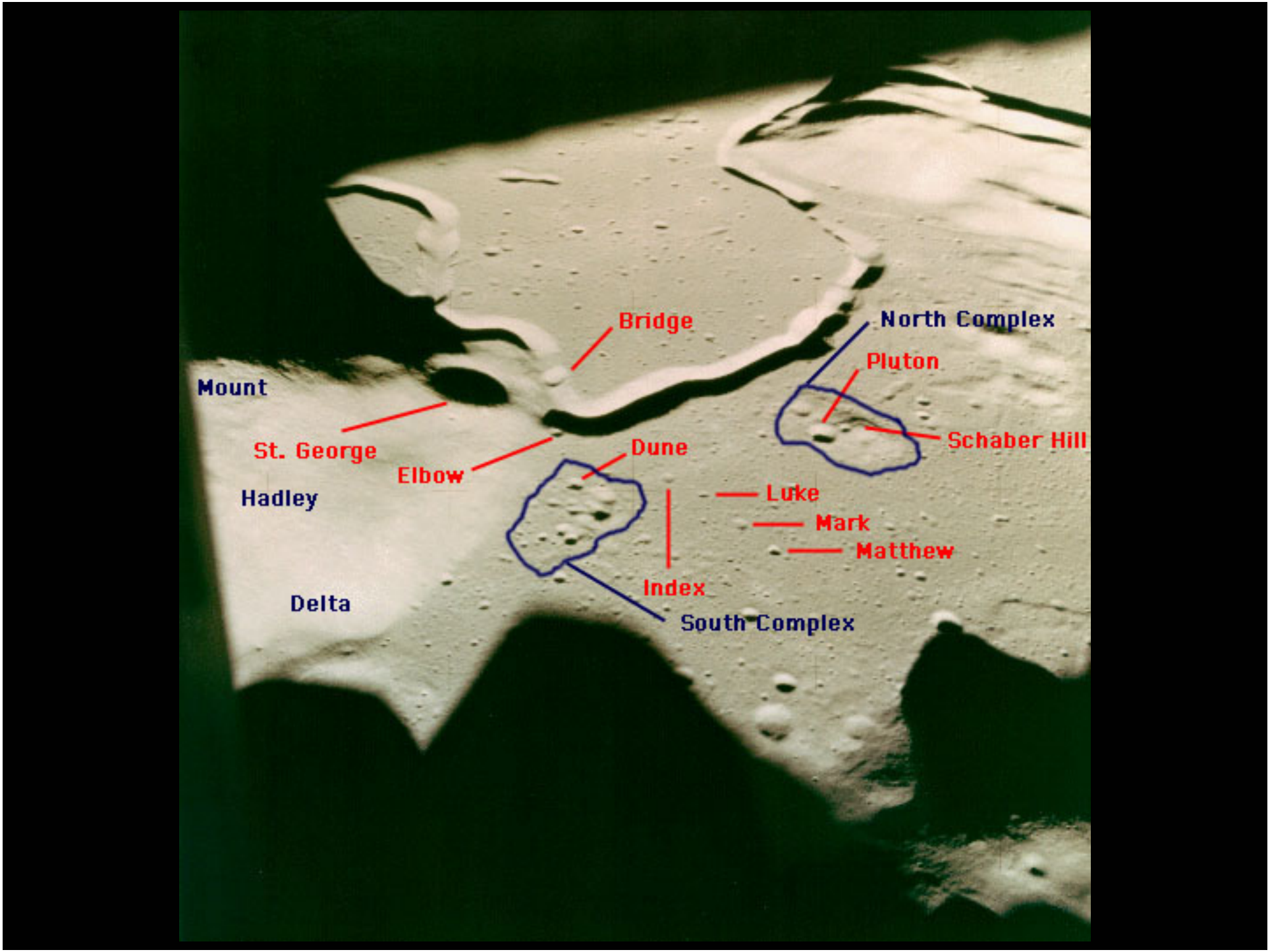


Figure credit: Lunar Sourcebook

Apollo 15 Hadley/Apennine

Objectives:	Sample mountainous rings of Imbrium basin (massifs and highlands) Sample lavas and landforms of Palus Putredinus (Hadley Rille and Mare Imbrium)
Results:	Highlands material composed of anorthosites, Mg-suite plutonic rocks, impact melts, and granulites Imbrium-type breccias are 3.5 Ga Other impact lithologies are ~3.9-4.1 Ga Two distinct chemical groups of mare basalts (quartz normative and olivine normative) Both groups of basalts have same age, ~3.3 Ga A nonmare basalt, aluminous and KREEP-rich discovered Volcanic (pyroclastic) ultramafic green glass spherules discovered
Conclusions:	Highlands have a complex composition Mare Imbrium not produced by impact Rille is a collapsed lava tube (with layers of lava visible)
Other notes:	First advanced (J) mission and first sent to a complex, multi-objective landing site


Bridge
North Complex
Pluton
Mount
St. George
Schaber Hill
Dune
Elbow
Hadley
Luke
Mark
Matthew
Index
Delta
South Complex


Surface: Dave Scott and Jim Irwin
Orbiting: Al Worden
North complex
RIMA HADLEY
Plain
Terrace
Apollo 15 landing site
Last
Index
PALUS PUTREDINIS
Rhysling
Earthlight
Bridge
Dune
South cluster
Elbow
Spur
St George
Apennine Front
1000 500 0 1 2 3 4
Meters
Kilometers
HADLEY DELTA

Apollo 15 Hadley/Apennine

Objectives:	Sample mountainous rings of Imbrium basin (massifs and highlands) Sample lavas and landforms of Palus Putredinus (Hadley Rille and Mare Imbrium)
Results:	Highlands material composed of anorthosites, Mg-suite plutonic rocks, impact melts, and granulites Imbrium-type breccias are 3.5 Ga Other impact lithologies are ~3.9-4.1 Ga Two distinct chemical groups of mare basalts (quartz normative and olivine normative) Both groups of basalts have same age, ~3.3 Ga A nonmare basalt, aluminous and KREEP-rich discovered Volcanic (pyroclastic) ultramafic green glass spherules discovered
Conclusions:	Highlands have a complex composition Mare Imbrium not produced by impact Rille is a collapsed lava tube (with layers of lava visible)
Other notes:	First advanced (J) mission and first sent to a complex, multi-objective landing site

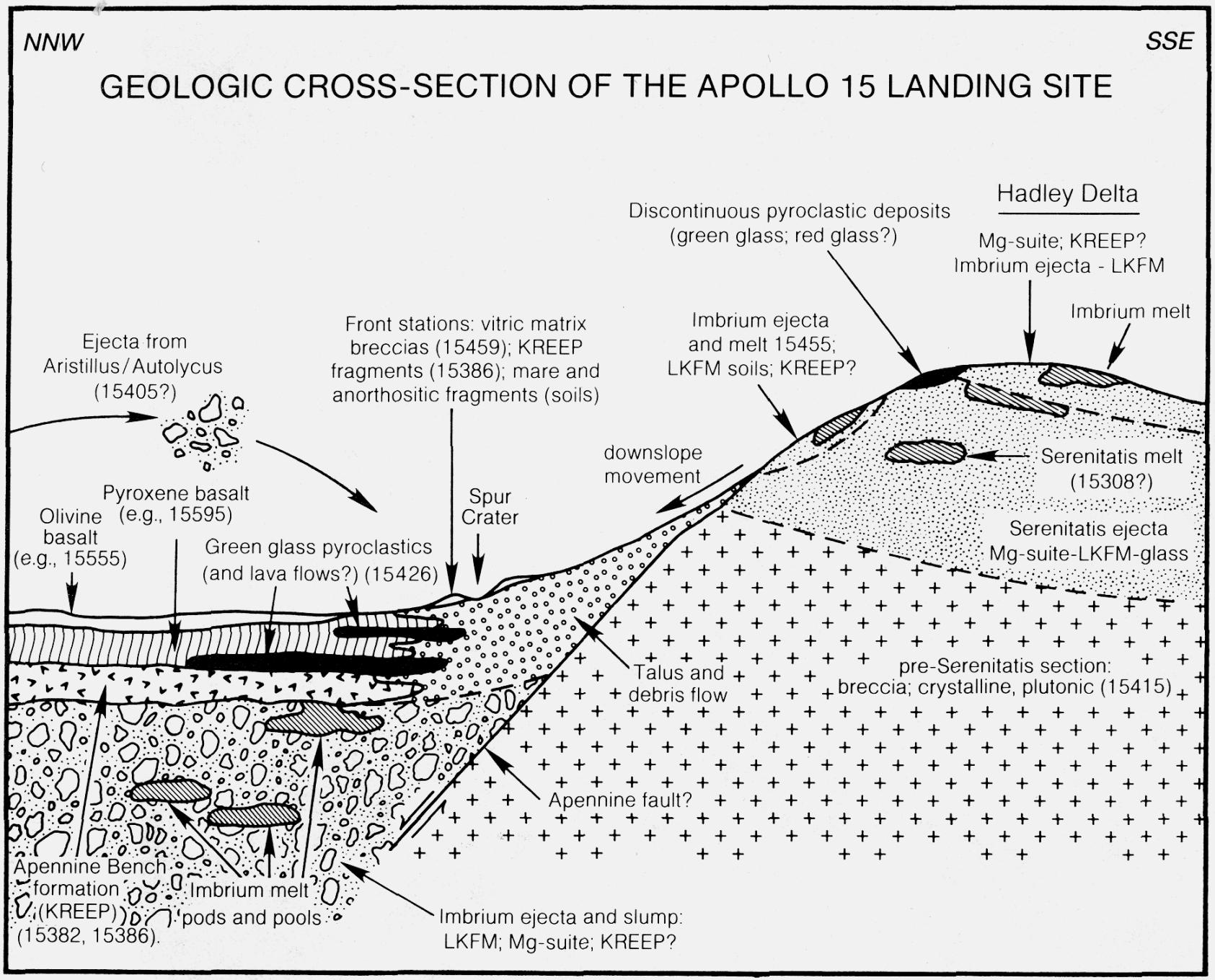
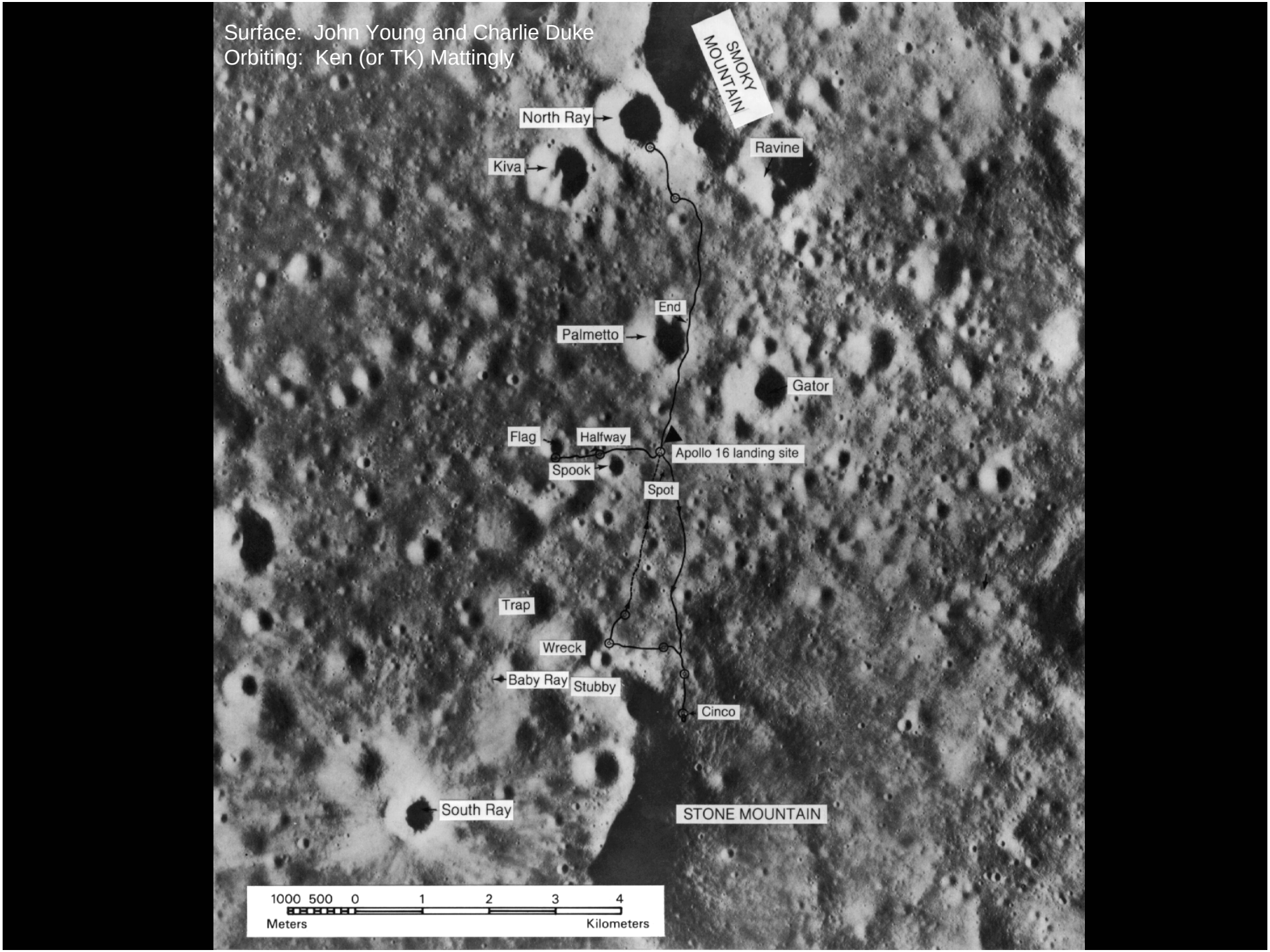


Figure credit: Lunar Sourcebook

Apollo 16 Descartes

Objectives:	Sample two units within the highland terrain, far from any mare material (relatively smooth Cayley Plains & hilly and furrowed Descartes material, both of which were suspected to be volcanic) Obtain heat flow in highlands
Results:	All samples are impact products (in sharp contrast to pre-mission expectations) Impact breccias ~3.9-4.2 Ga Sample from Nectaris Basin is 3.92 Ga
Conclusions:	Most flat highland areas formed by ponded impact ejecta; probably related to major multi-ring impact basins Highlands are dominantly anorthositic


Surface: John Young and Charlie Duke
Orbiting: Ken (or TK) Mattingly
SMOKY MOUNTAIN
North Ray
Ravine
Kiva
End
Palmetto
Gator
Flag
Halfway
Apollo 16 landing site
Spook
Spot
Trap
Wreck
Baby Ray
Stubby
Cinco
South Ray
STONE MOUNTAIN
1000 500 0 1 2 3 4
Meters
Kilometers

Apollo 16 Descartes

Objectives:	Sample two units within the highland terrain, far from any mare material (relatively smooth Cayley Plains & hilly and furrowed Descartes material, both of which were suspected to be volcanic) Obtain heat flow in highlands
Results:	All samples are impact products (in sharp contrast to pre-mission expectations) Impact breccias ~3.9-4.2 Ga Sample from Nectaris Basin is 3.92 Ga
Conclusions:	Most flat highland areas formed by ponded impact ejecta; probably related to major multi-ring impact basins Highlands are dominantly anorthositic

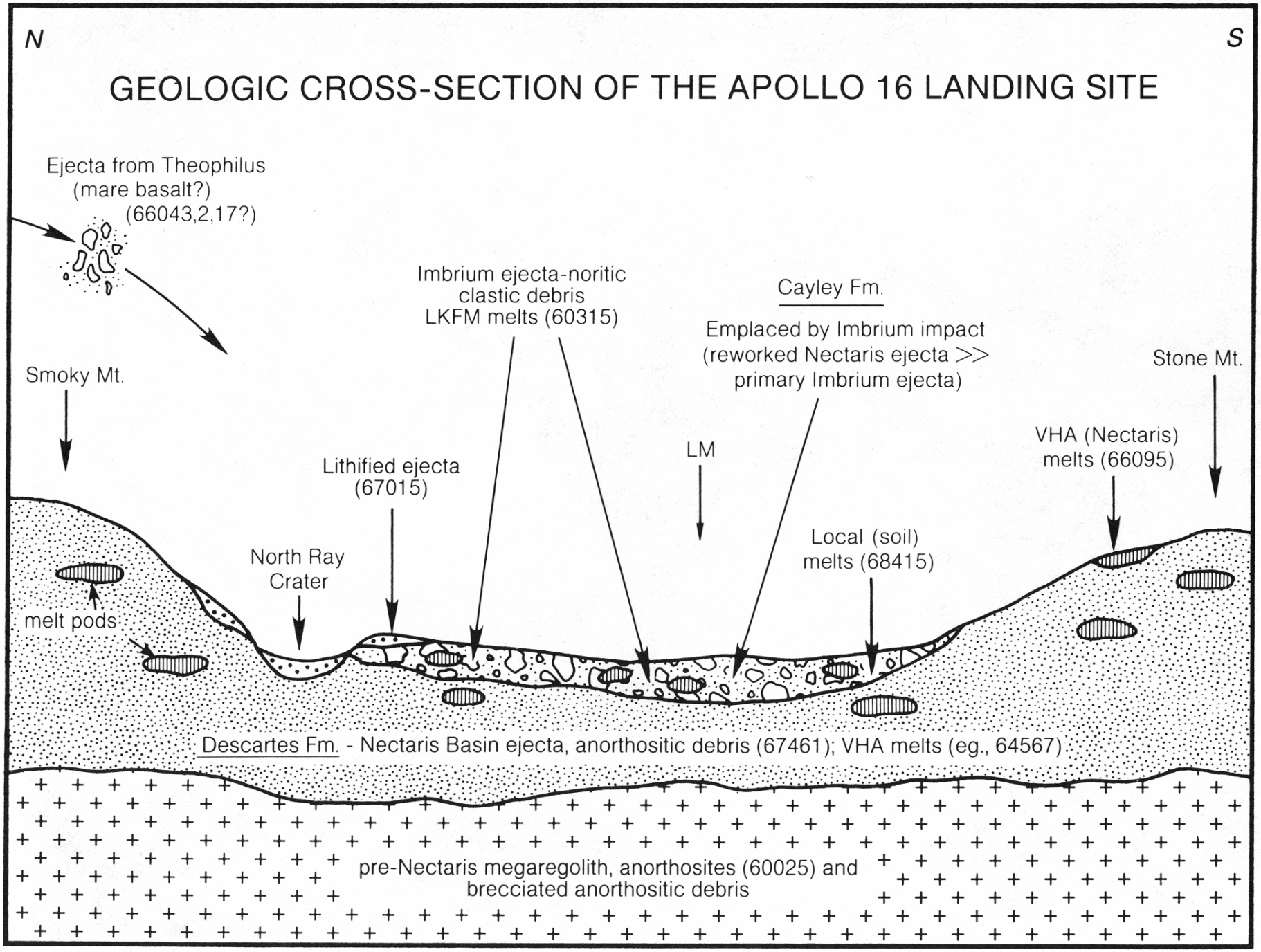
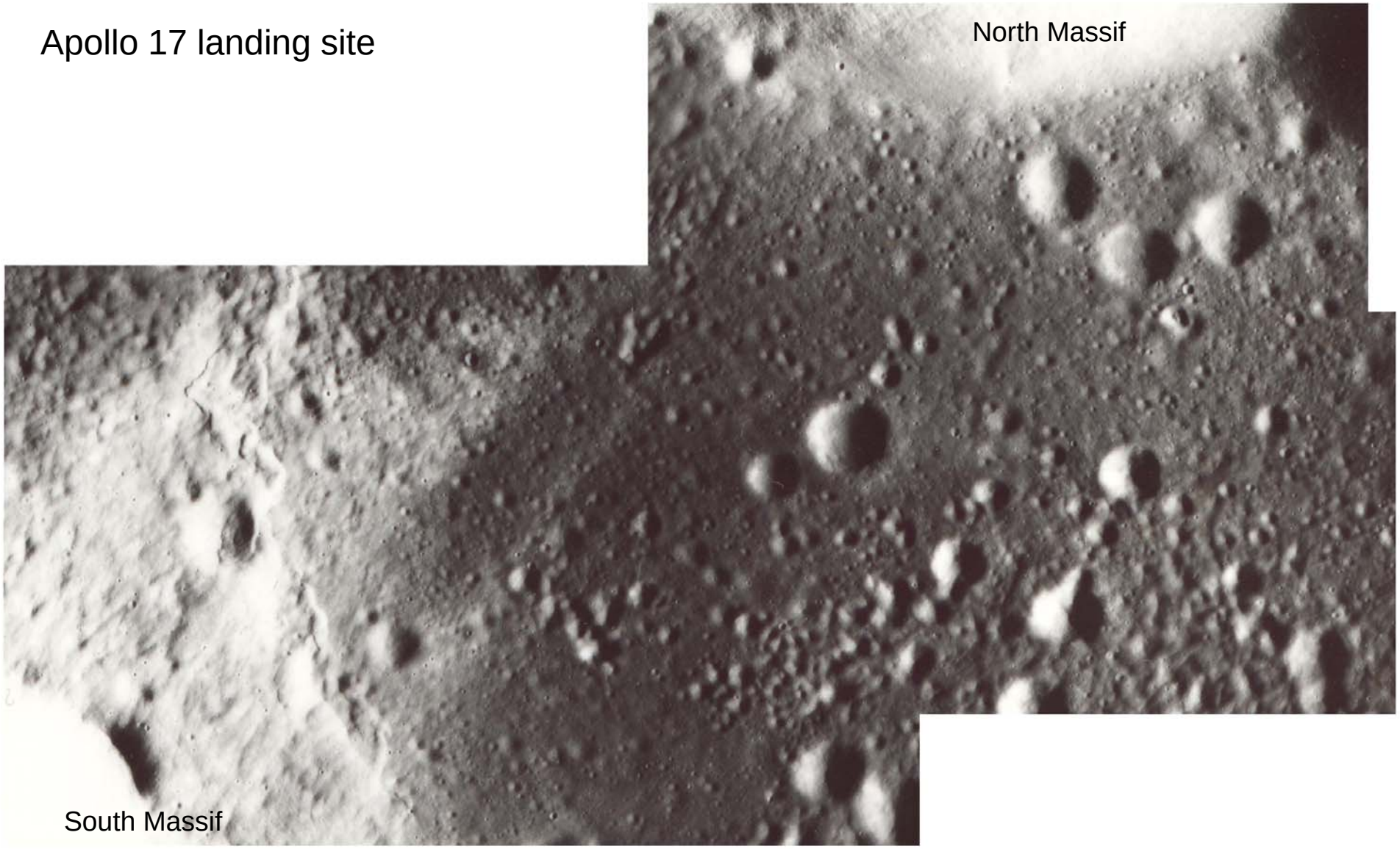


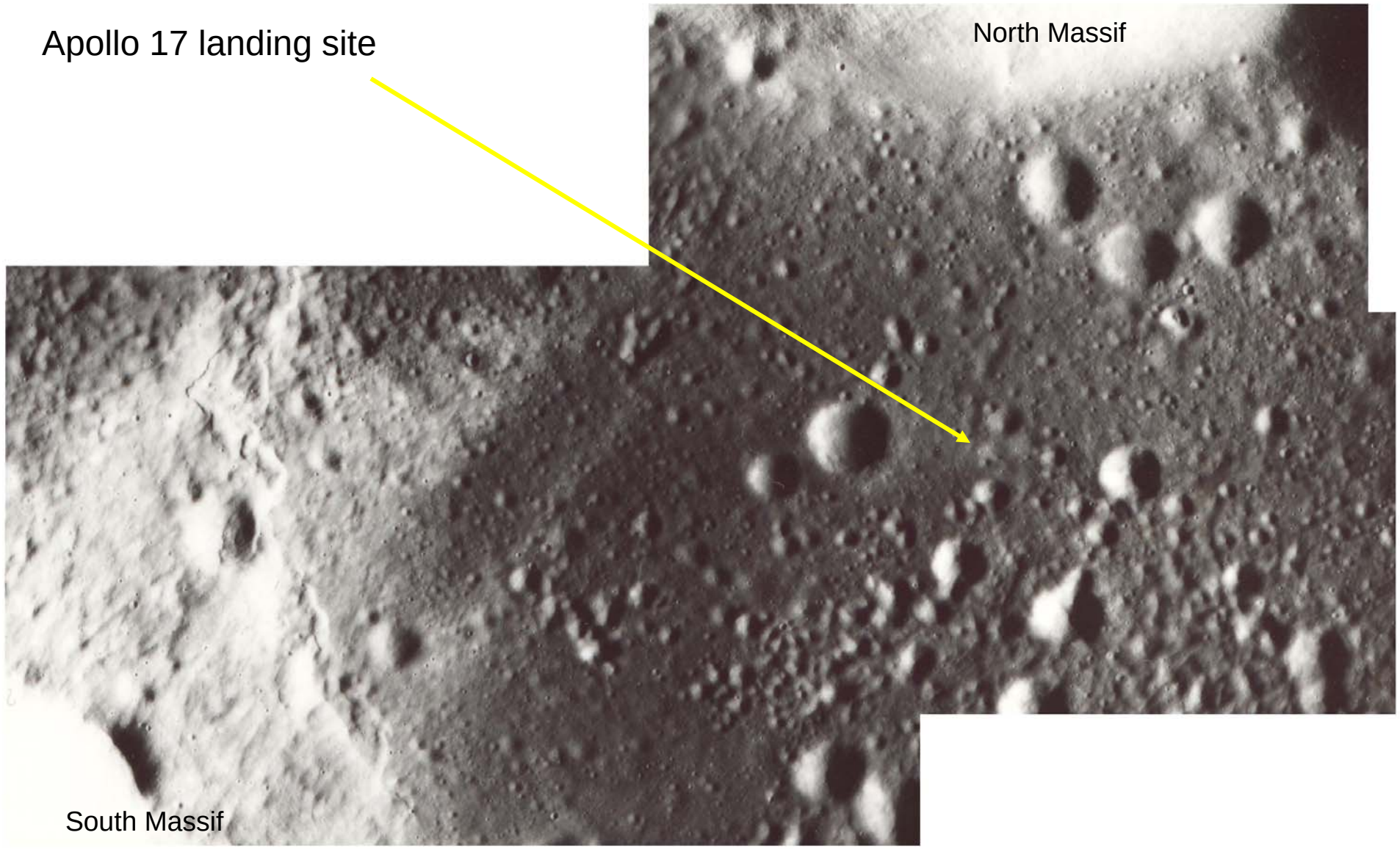
Figure credit: Lunar Sourcebook

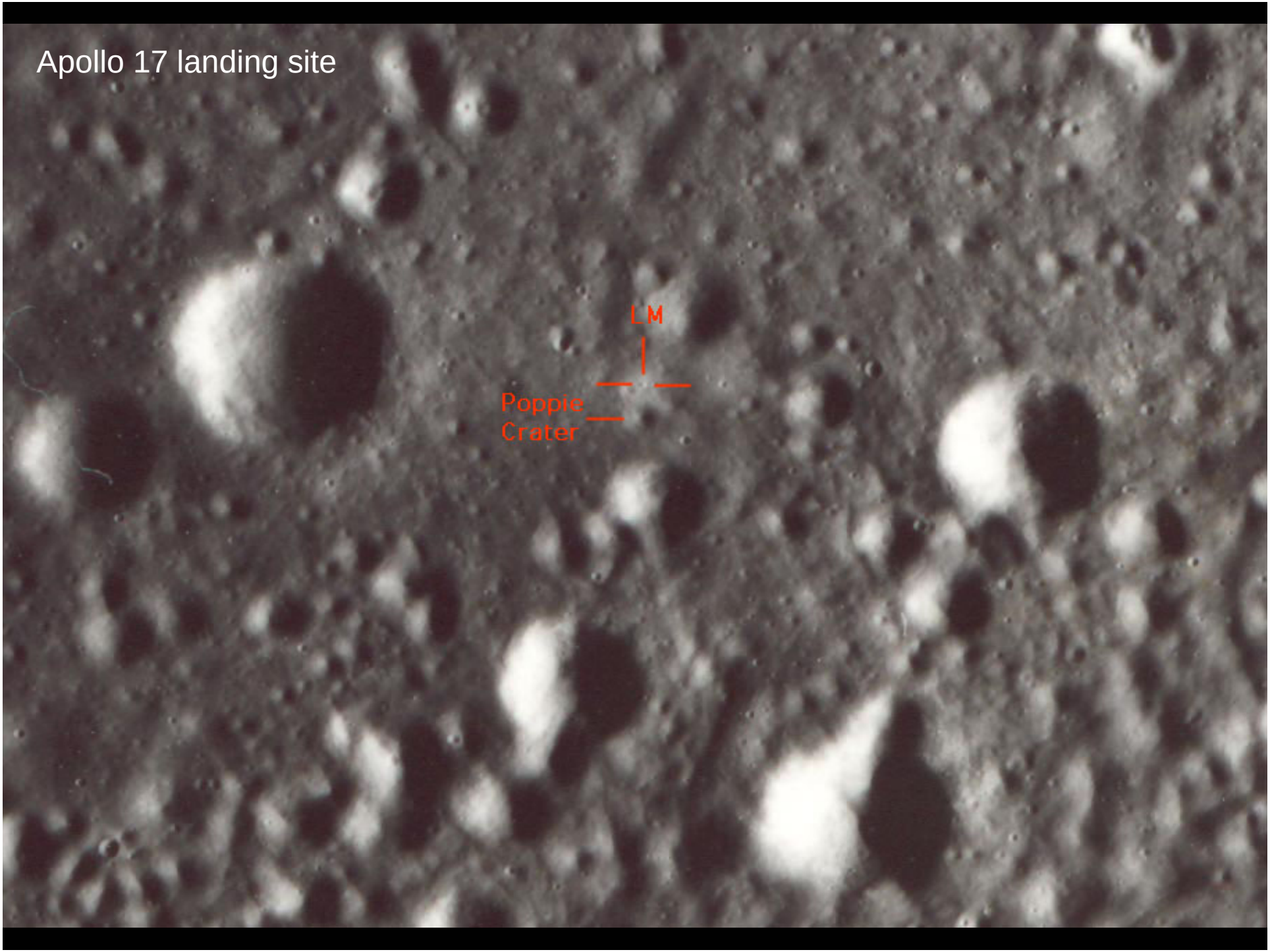
Apollo 17 Taurus-Littrow

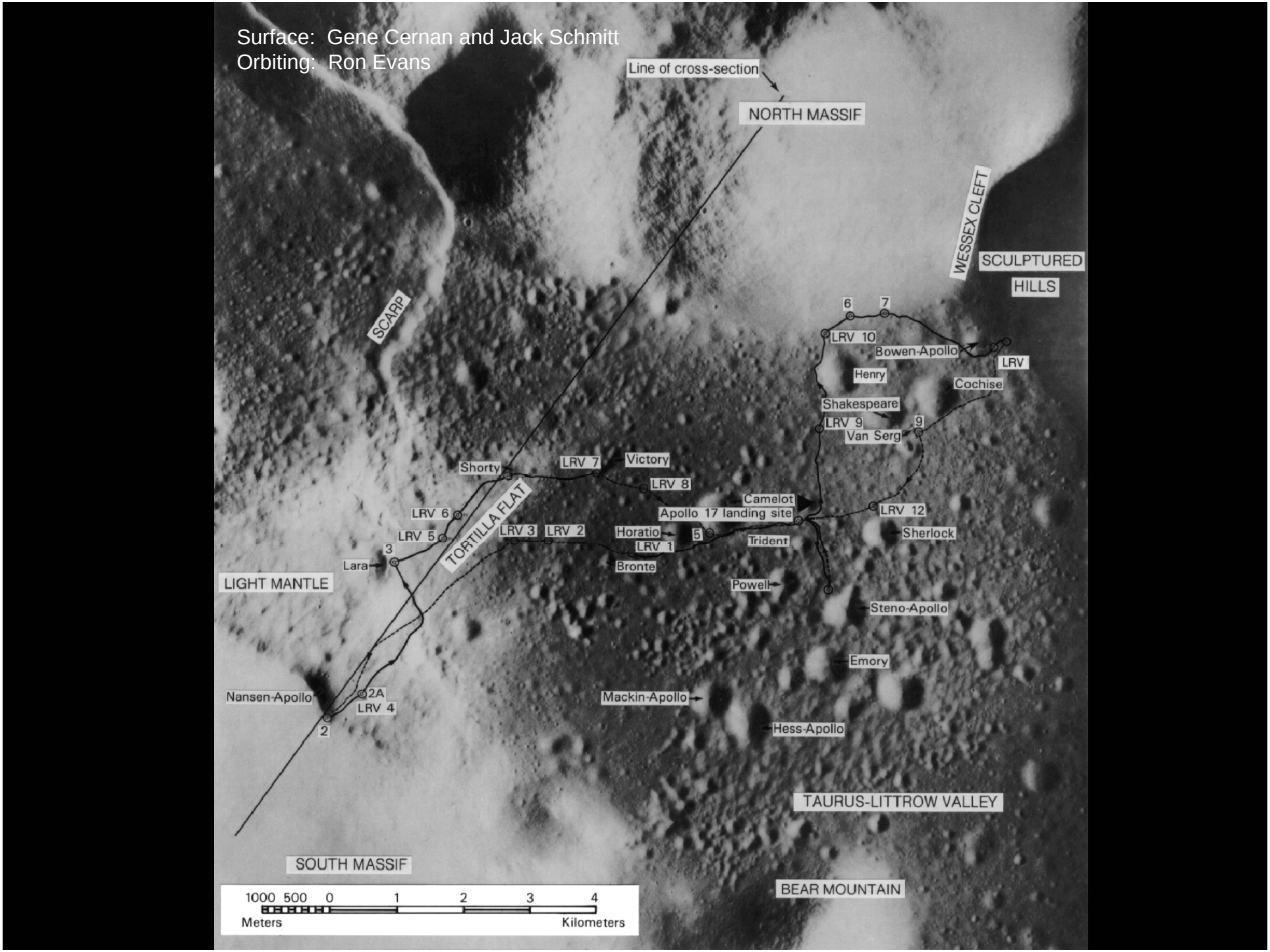
Objectives:	Explore highland/mare boundary near SE rim of Serenitatis Sample massifs from an older basin (Serenitatis), perhaps from deep within lunar crust Sample Taurus-Littrow Valley floor, which was suspected to be composed of mare basalts Sample dark material that discontinuously covers highlands and mare material at the site
Results:	Massifs are composed of impact melt breccias and Mg-suite plutonic rocks Impact breccias ~3.87 Ga, possibly age of Serenitatis Basin Basalts are similar to those at Apollo 11 (high Fe and Ti) and have a similar age of ~3.7 to 3.8 Ga Dark mantling material is orange and black pyroclastic glass spherules ~3.5 Ga Landslide from South Massif occurred 100 Ma and may have been caused by Tycho impact (~2000 km distant)
Conclusions:	Very young volcanism is not evident No anorthosites Orange glass does not imply water

Apollo 17 landing site




Apollo 17 landing site
North Massif
South Massif


Apollo 17 landing site
LM
Poppie
Crater


Surface: Gene Cernan and Jack Schmitt
Orbiting: Ron Evans
Line of cross-section
NORTH MASSIF
WESSEX CLEFT
SCULPTURED HILLS
SCARP
6
7
LRV 10
Bowen-Apollo
LRV
Henry
Cochise
Shakespeare
LRV 9
9
Van Serg
Shorty
LRV 7
Victory
LRV 8
Camelot
Apollo 17 landing site
LRV 12
LRV 6
LRV 5
TORTILLA FLAT
LRV 3
LRV 2
Horatio
5
Trident
Sherlock
LRV 1
3
Lara
Bronte
LIGHT MANTLE
Powell
Steno-Apollo
Emory
Nansen-Apollo
2A
LRV 4
2
Mackin-Apollo
Hess-Apollo
TAURUS-LITTROW VALLEY
SOUTH MASSIF
BEAR MOUNTAIN
1000 500 0 1 2 3 4
Meters
Kilometers

Apollo 17 Taurus-Littrow

Objectives:	Explore highland/mare boundary near SE rim of Serenitatis
	Sample massifs from an older basin (Serenitatis), perhaps from deep within lunar crust
	Sample Taurus-Littrow Valley floor, which was suspected to be composed of mare basalts
	Sample dark material that discontinuously covers highlands and mare material at the site
Results:	Massifs are composed of impact melt breccias and Mg-suite plutonic rocks
	Impact breccias ~3.87 Ga, possibly age of Serenitatis Basin
	Basalts are similar to those at Apollo 11 (high Fe and Ti) and have a similar age of ~3.7 to 3.8 Ga
	Dark mantling material is orange and black pyroclastic glass spherules ~3.5 Ga
	Landslide from South Massif occurred 100 Ma and may have been caused by Tycho impact (~2000 km distant)
Conclusions:	Very young volcanism is not evident
	No anorthosites
	Orange glass does not imply water

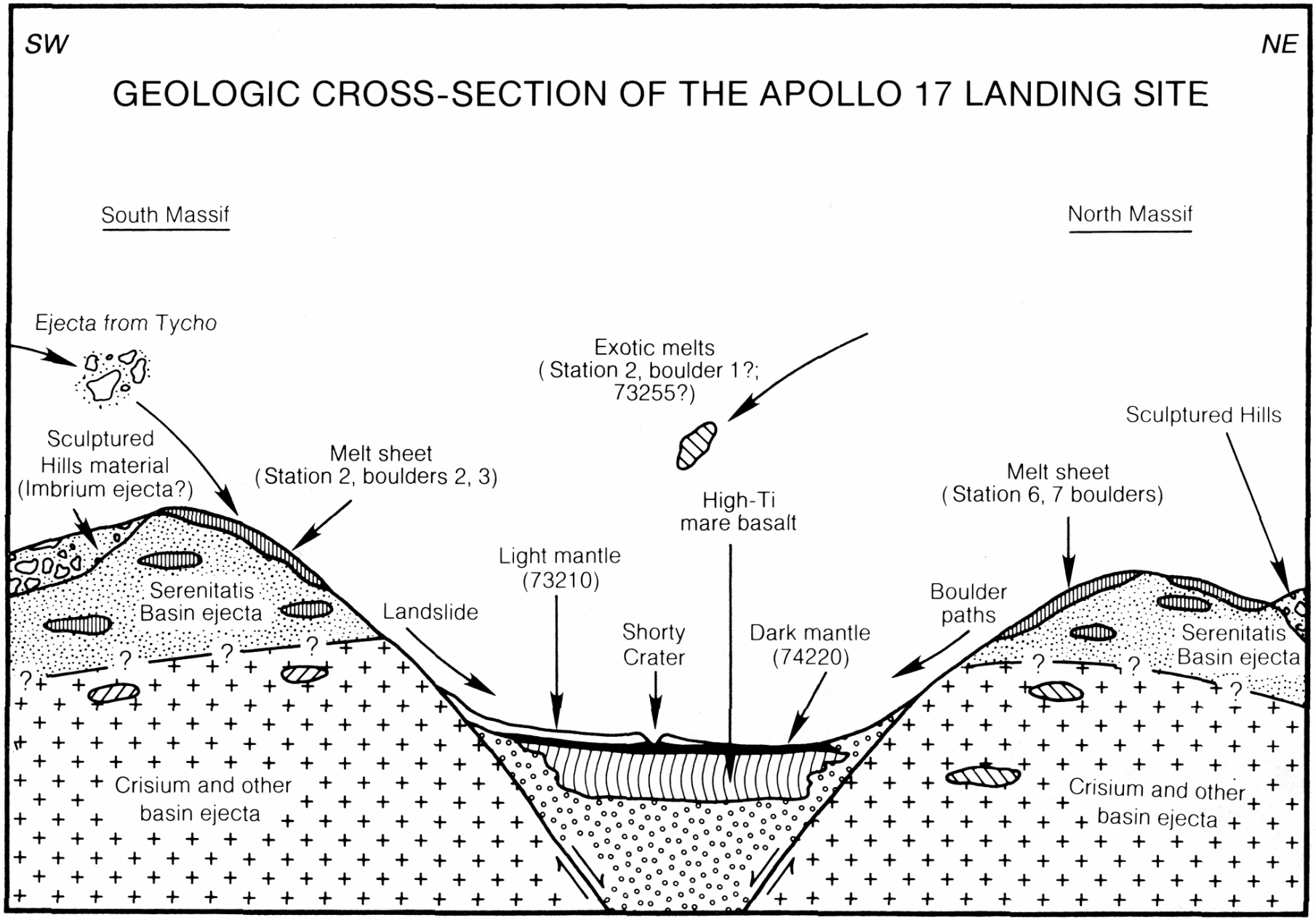
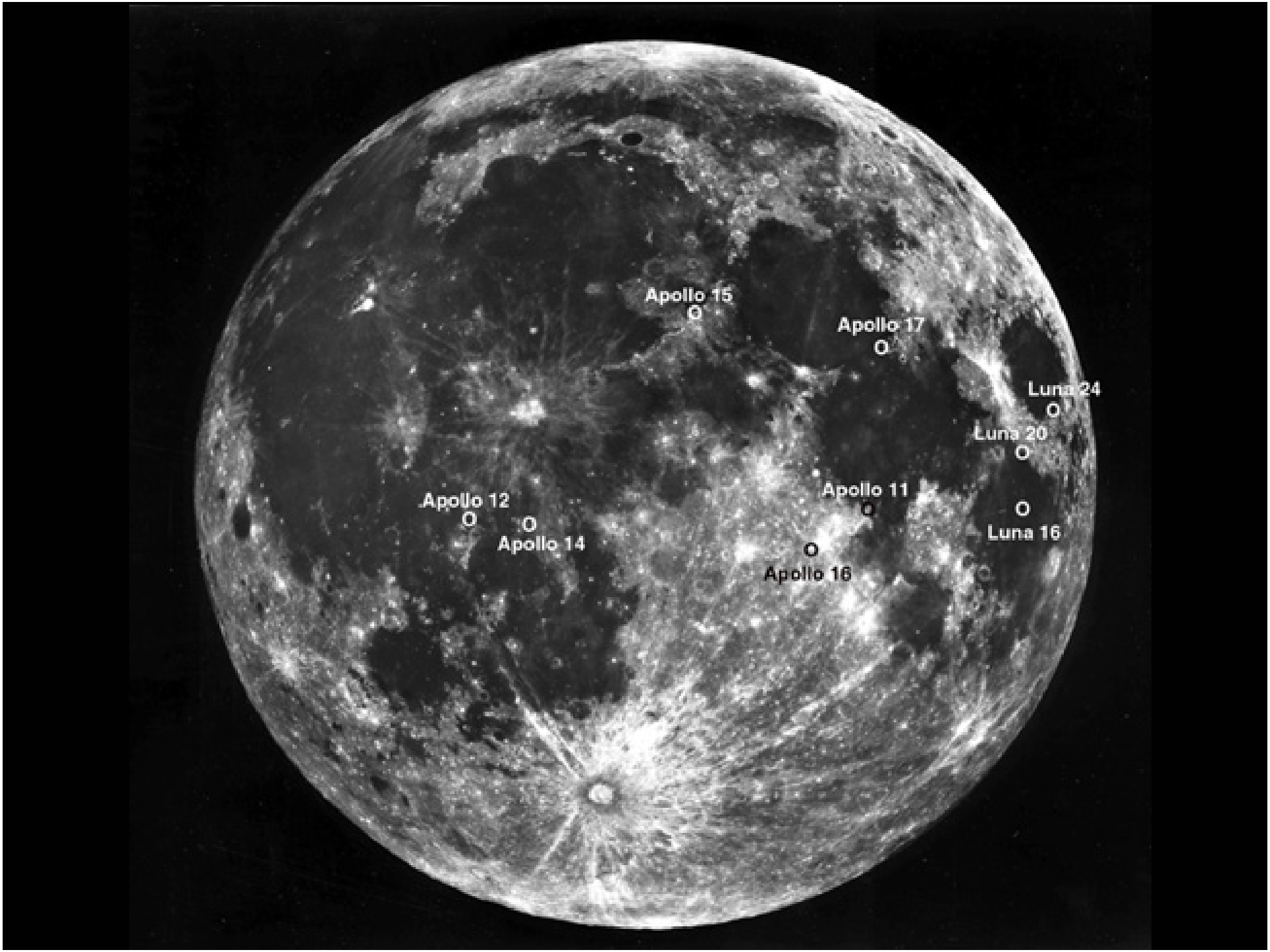


Figure credit: Lunar Sourcebook


Apollo 15
Apollo 17
Luna 24
Luna 20
Apollo 11
Apollo 12
Apollo 14
Luna 16
Apollo 16

Luna 16, 20, and 24

Luna 16	Landed in northern Mare Fecunditatis
	Found mare basalt regolith that is moderately-high-Ti and high-Al in composition; erupted 3.41 Ga
Luna 20	Landed in the highlands south of the Crisium Basin
	Found anorthositic regolith (granulite, anorthosite, impact melt, and polymict breccia)
Luna 24	Landed in southern Mare Crisium
	Found mare regolith with very-low-Ti basalt (also high in Fe and Al), with basalt ages ranging from 3.4 to 3.6 Ga

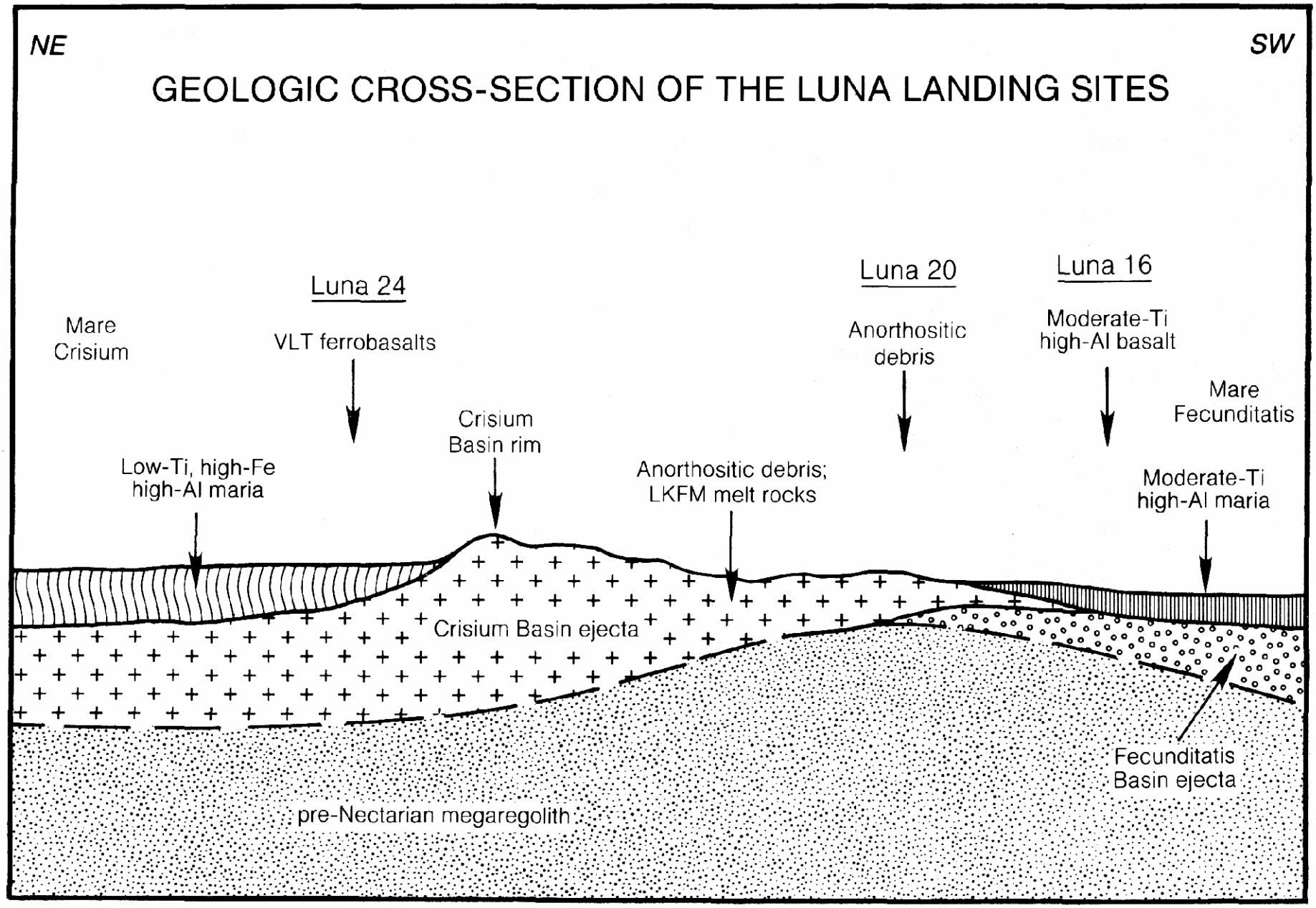


Figure credit: Lunar Sourcebook